
सिरैमिक उद्योग के
लिए चीनी मिट्टी — विशीष्टि
(तीसरा पुनरीक्षण)

China Clay for
Ceramic Industry — Specification
(Third Revision)

ICS 81.060.10

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भारतीय मानक ब्यूरो
BUREAU OF INDIAN STANDARDS
मानक भवन, 9 बहादुरशाह ज़फर मार्ग, नई दिल्ली – 110002
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI-110002
www.bis.gov.in www.standardsbis.in

FOREWORD

This Indian Standard (Third Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Ceramicware Sectional Committee had been approved by the Chemical Division Council.

This standard was originally published in 1965 and later revised in 1993 and 2002.

China clay is the most important raw material for ceramic industry. With time, different grades of clay (other than those mentioned in the previous standards) are being used in the industry. In the first revision, a new grade was introduced as Grade I and new requirements like degree of whiteness, green MOR, fired characteristics, Atterberg number and particle size distribution were included.

In the second revision, the requirement of fired colour had been included and the requirements of Atterberg number, apparent porosity and water absorption had been modified in the light of experience gained.

In this third revision, temperature for fired characteristics, fired colour and maturity have been modified. Formula to calculate loss on ignition has been added. To determine particle size distribution, laser diffraction technique has been permitted. Requirement and test method for calcium as calcium oxide have also been added.

The composition of the committee responsible for the formulation of this standard is given at Annex D.

For the purpose of deciding whether a particular requirement of this standard is complied with the final value, observed or calculated, expressing the result of a test or analysis shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

CHINA CLAY FOR CERAMIC INDUSTRY — SPECIFICATION

(*Third Revision*)

1 SCOPE

This standard prescribes requirements, and methods of sampling and test for china clay for use in ceramic industry.

2 REFERENCES

The following Indian Standards contain provisions, which through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below:

<i>IS No.</i>	<i>Title</i>
264 : 2005	Nitric acid — Specification (<i>third revision</i>)
265 : 1993	Hydrochloric acid — Specification (<i>fourth revision</i>)
266 : 1993	Sulphuric acid — Specification (<i>third revision</i>)
323 : 2009	Rectified spirit for industrial use — Specification (<i>second revision</i>)
460 (Part 1) : 1985	Test sieves: Part 1 Wire cloth test sieves (<i>third revision</i>)
1070:1992	Reagent grade water (<i>third revision</i>)
2781 : 2020	Glossary of terms relating to ceramicware (<i>third revision</i>)
2837 (Part 2) : 1977	Porcelain crucibles and basins: Part 2 Basins (<i>first revision</i>)
10332 : 1982	Specification for hydrofluoric acid, aqueous

3 TERMINOLOGY

For the purpose of this standard, terms and definitions given in IS 2781 shall apply.

4 GRADES

The material shall be of three grades, namely, Grade 1, Grade 2 and Grade 3 (*see* Table 1).

5 REQUIREMENTS

5.1 Material

The material shall be the natural mineral consisting essentially of hydrated aluminium silicate, suitably beneficiated to remove extraneous substances.

5.2 The material shall also comply with the requirements of Table 1 when tested in accordance with methods given in Annex A.

5.3 The moisture content of the material shall be as agreed to between the purchaser and the supplier. Where moisture content is specified by the purchaser, it shall be determined by the method specified in Annex B.

6 PACKING AND MARKING

6.1 Packing

The material shall be packed in jute bags or as agreed to between the purchaser and the supplier.

6.2 Marking

The bags shall be securely stitched and marked indelibly with the following information:

- Name and grade of the material,
- Indication of source of manufacture, and
- Net mass in kg.

6.3 BIS Certification Mark

The product(s) conforming to the requirements of this standard may be certified as per the conformity assessment schemes under the provisions of the *Bureau of Indian Standards Act, 2016* and the Rules and Regulations framed thereunder, and the products may be marked with the Standard Mark.

7 SAMPLING

7.1 Representative samples of the material shall be drawn as prescribed in Annex C.

7.2 Number of Tests and Criteria for Conformity

7.2.1 One laboratory sample from each sub-lot shall be tested individually for all the requirements of

this specification and the sub-lot shall be considered satisfactory if the laboratory sample satisfies all the requirements of this specification.

7.2.2 The lot shall be declared to be conforming to the requirements of the specification if all the sub-lots (see 7.2.1) are found satisfactory.

Table 1 Requirements for China Clay for Ceramic Industry
(Clauses 4, 5.2 and A-16.4.1)

Sl No.	Characteristic	Requirement			Method of Test (Ref to Clause of Annex A)
		Grade 1	Grade 2	Grade 3	
(1)	(2)	(3)	(4)	(5)	(6)
i)	Grit content/fineness (residue on 45 micron IS sieve), percent by mass, <i>Max</i>	0.5	1.0	2.0	A-2
ii)	Particle size distribution, percent by mass:				A-3 or an X-ray based equipment
	a) Coarser than 25 microns, <i>Max</i>	5	7	10	
	b) Finer than 10 microns, <i>Min</i>	85	80	75	
	c) Finer than 2 microns, <i>Min</i>	70	65	60	
iii)	Plasticity by hand feel test	Very good	Good	Fair	A-4
iv)	Water of plasticity, percent by mass, <i>Min</i>	32	30	28	A-5
v)	Atterberg number, <i>Min</i>	12	10	8	A-6
vi)	Loss on ignition, percent by mass, <i>Min</i>	13.0	12.0	10.0	A-7
vii)	Alumina (as Al_2O_3), percent by mass, <i>Min</i>	37.0	34.0	32.0	A-8
viii)	Oxide of iron (as Fe_2O_3), percent by mass, <i>Max</i>	0.8	1.0	1.5	A-9
ix)	Titania (as TiO_2), percent by mass, <i>Max</i>	0.7	1.0	1.0	A-10
x)	Oxide of iron (as Fe_2O_3) and Titanium (as TiO_2) together, percent by mass, <i>Max</i>	1.5	2.0	2.5	A-9 and A-10
xi)	Dry linear shrinkage (at 110 °C), percent, <i>Max</i>	6	7	8	A-11
xii)	Green MOR, MPa (on drying at 110 °C), <i>Min</i>	1.0	0.7	0.6	A-12
xiii)	Fired characteristic at 1 200 °C	Should be free from black speck/spots and cracks			
xiv)	Fired colour	White	Cream	Light buff	A-13.4.1
xv)	Water absorption (Maturity), percent by mass, <i>Max</i>	15	13	11	A-13
xvi)	Apparent porosity, <i>Max</i>	26	24	21	A-14
xvii)	Total linear shrinkage (after firing at 1 200 °C), percent, <i>Max</i>	16	17	18	A-15
xviii)	PCE value in Orton, <i>Min</i>	34	32	28	A-16
xix)	Calcium (as CaO), percent by mass, <i>Max</i>	0.7	0.7	0.7	A-17

ANNEX A

(Clause 5.2)

METHODS OF TEST

A-1 GENERAL

A-1.1 Test for physical and chemical requirements on china clays shall be carried out on clay samples as prepared in C-5.

A-1.2 Unless otherwise specified, pure chemicals and distilled water (see IS 1070) shall be used in tests.

NOTE — 'Pure chemicals' shall mean chemicals that do not contain impurities which affect the result of analysis.

A-2 DETERMINATION OF GRIT CONTENT/FINENESS

A-2.1 Outline of the Method

Clay is crushed to pass a 250-micron IS sieve and deflocculated in water using sodium carbonate. The slurry is then sieved through 45-micron IS sieve and the residue retained on it is reported as grit.

A-2.2 Apparatus

A-2.2.1 Balance

A physical balance sensitive to 0.1 g and an analytical balance sensitive to 0.001 g.

A-2.2.2 Mechanical Stirrer

The stirrer shall essentially be a mechanically operated stirring device in which a suitably mounted electric motor turns a vertical shaft at a speed of not less than 1 000 rev/min without load. The shaft shall be fitted with a replaceable stirring paddle, made of non-rusting metal, plastics or hard rubber. A special dispersion cup, fitted with wire baffles, shall be provided to hold the sample.

A-2.2.3 Sieves

250-micron and 45-micron IS sieves [see IS 460 (Part 1)].

A-2.3 Preparation of Sample

Crush the clay sample to pass completely through a 250-micron IS sieve. Place in an air oven, dry at 105 to 110 °C for not less than 5 h and then cool in a desiccator.

A-2.4 Procedure

A-2.4.1 Weigh about 250 g of the sample prepared in A-2.3 to the nearest 0.1 g and transfer to a glass container of 2 l capacity. Wet the clay sample with 1 000 ml of distilled water containing 0.2 percent sodium carbonate, by mass of the sample taken for the test. Allow to settle for 24 h and then blend with the mechanical stirrer for 30 min.

A-2.4.2 Transfer the mixture to the 45-micron IS sieve and wash it through the sieve with a gentle flow of water from a rubber hose until the water passing through the sieve appears to be clear and free from cloudiness. Take due care to prevent any loss of sample because of splashing or overflowing. Dry the sieve with residue at 110 ± 5 °C for 2 h.

A-2.4.3 Carefully brush the residue on to a tared watch glass and weigh to the nearest 0.001 g.

A-2.5 Calculation

A-2.5.1 Grit content, percent by mass = $\frac{M_1}{M} \times 100$

where

M_1 = mass of the residue in g, and

M = mass in g of the prepared sample (A-2.4.1) taken for the test.

A-2.5.2 Report the average result of three determinations. Result of each determination shall agree within ± 0.1 percent of the average value. If any result does not agree within the tolerance limit, it shall be rejected and the test shall be repeated.

A-3 DETERMINATION OF PARTICLE SIZE DISTRIBUTION

A-3.1 Principle

The progress of sedimentation of clay suspension in a tall cylinder is followed by withdrawing sample portions at a known depth, based on the temperature of the suspension below the surface, with a pipette and weighing the sediment. Stoke's law is then applied to find out grain size which is expressed as the width of a cube.

A-3.2 Apparatus

A-3.2.1 *Andreasen's Pipette* — The pipette (see Fig. 1) consists of the following:

- a) *Sedimentation cylinder* — A glass sedimentation vessel (W) with about 5.3 - 5.4 cm internal diameter having a graduated scale 0 to 20 cm with sub-graduation in mm or 0-200 mm marked on the side of the vessel. The zero mark of the scale should be 4-5 cm but not less than 4.0 cm from the inside base of the vessel. The capacity of the vessel, after inserting the pipette (P) in the vessel (W) and when filled with water up to the 20 cm mark, should be exactly 550 ml with three-way stopcock in open position. The vessel is provided with a neck to take a pipette through a ground glass stopper.

b) *Pipette* — The pipette has a bulb (see Fig.1) and is provided with a two-way tap and side discharge tube. The capacity of the pipette up to the graduation line, when the tap is in a 'closed' position, is 10 ml. A bell-shaped dome is fused to the capillary stem of the pipette below the tap to provide a ground glass joint to fit the neck of the sedimentation vessel. A small vent hole is made in the dome to avoid creation of low pressure in the pipette during successive sampling. The tip of the stem, when the pipette is fitted to the vessel, shall be level with the zero mark of the scale. The stem of the pipette from the bulb to the two-way stopcock and after is constructed of capillary glass tube having a bore diameter between 1.0 mm and 1.3 mm. The tube above the bulb should have a bore diameter of 4.0 to 4.5 mm.

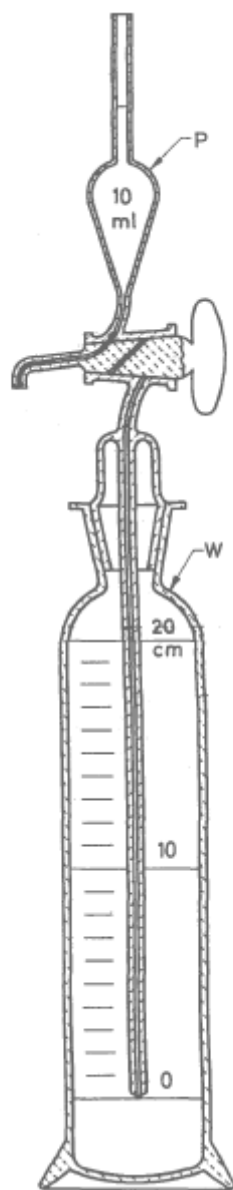


FIG.1 ANDREASEN'S PIPETTE

A-3.2.2 Basin — Silica or porcelain basin [see IS 2837 (Part 2)].

A-3.3 Reagents

A-3.3.1 Sodium Pyrophosphate Solution — Dissolve 24.5 g of sodium pyrophosphate ($\text{Na}_4\text{P}_2\text{O}_7 \cdot 10\text{H}_2\text{O}$) in 500 ml of distilled water.

A-3.4 Procedure

A-3.4.1 Preparation of Sample

Crush the clay sample to pass completely through a 250 micron IS sieve. Dry a portion of the sample (~ 15 g) at $110 \pm 2^\circ\text{C}$ to constant mass.

A-3.4.2 Place 5.50 g of dried clay sample in a 250 ml wide mouth bottle and add 200 ml of distilled water. Allow to stand for 24 h. Add 10 ml of the sodium pyrophosphate solution. Agitate the bottle with its contents by rotating end-over-end for 17 h.

NOTE — This is best done by packing the bottle in the jar of a pot mill so as to turn end-over-end as the mill rotates.

A-3.4.3 Transfer the dispersed sample to the Andreasen's pipette and first add distilled water to bring the level of the suspension at about 18-cm mark on the scale. Insert the pipette in the vessel with stopcock in an open position. Bring the level of the suspension up to 20 cm mark on the scale by adding distilled water, making up the total volume to 550 ml.

NOTE — This produces a 1 percent suspension, and the concentration of the electrolyte is 0.002 g mole ($\text{Na}_4\text{P}_2\text{O}_7 \cdot 10\text{H}_2\text{O}$) per litre.

A-3.4.4 Place the Andreasen's pipette in a water bath maintained at a constant temperature (see Table 2) for at least 30 min to permit it to attain the temperature of the bath. Remove it, shake by hand for two minutes and replace immediately into the bath. Hold the pipette for about 30 s to attain stability and then start counting of time by a stop watch for the initial period. Withdraw 10 ml of suspension at increasing intervals of time, at a uniform rate of about 20 s as withdrawal time. The samples are drawn at intervals of 2, 5, 10 and 30 min and then at 1, 2, 4, 6 and 24 h.

NOTE — These intervals are chosen arbitrarily, but should be adhered to in order to save time in calculating the grain size.

A-3.4.5 Take 10 ml aliquots in small, weighed basins and evaporate to dryness at 110°C . Weigh the residue accurately to 0.1 mg.

A-3.5 Calculation

Calculate the percentage of net dried residue making a correction for the sodium pyrophosphate content in the mass of the dried residue by subtracting 0.005 3 g, as follows:

Net dried residue, percent by mass,

$$M = \frac{(M_1 - 0.0053) \times 100}{M_2}$$

where

M_1 = mass of the dried residue, and

M_2 = theoretical mass of the clay sample in 10 ml of suspension.

Table 2 Values of Viscosity and Density of Water
(Clauses A-3.4.4 and A-3.6.2)

SI No.	Temperature, °C	Viscosity, g/cm.s	Density, g/cm ³
(1)	(2)	(3)	(4)
i)	10	0.013 10	0.999 7
ii)	20	0.010 09	0.998 2
iii)	25	0.008 95	0.997 0
iv)	27	0.008 55	0.996 5
v)	30	0.008 00	0.995 6
vi)	40	0.006 56	0.992 3

A-3.6 Calculation of Particle Size Distribution

A-3.6.1 The particle size distribution is calculated by applying the Stoke's law which may be stated as follows:

$$r = \sqrt{\frac{9h\eta}{2(D_1 - D_2)gt}} \quad \dots (1)$$

where

r = radius of spherical particle, in cm;

h = height of the liquid surface from the tip of the pipette before the suspension is withdrawn, in cm;

η = viscosity of the suspending medium at the temperature of the test, in g/cm.s;

D_1 = density of the solid particle, in g/cm³;

D_2 = density of the suspending medium at the temperature of test, in g/cm³;

g = acceleration due to gravity (979 cm/s²); and

t = time from the start of the test, in s.

For a solid suspended in a liquid medium, the fraction $9\eta/2(D_1 - D_2)g$ is constant at a given temperature and

can be evaluated. Thus, equation (1) may be expressed as follows:

$$r = k \sqrt{\frac{h}{t}} \quad \dots (2)$$

Where

$$k = \sqrt{\frac{9\eta}{2(D_1 - D_2)g}} \quad \dots (3)$$

A-3.6.2 Substituting in equation (3) the values for:

a) Density of clay, $D_1 = 2.625$ g/cm³ approx. (Determine the specific gravity of the clay sample by using pycnometer as per the standard procedure);

b) Acceleration due to gravity, $g = 979$ cm/s² (see A-3.6.1);

c) Viscosity of suspending medium (water) at 40 °C, $\eta = 0.00656$ g/cm.s (see Table 2); and

d) Density of suspending medium (water) at 40 °C, $D_2 = 0.9923$ g/cm³ (see Table 2).

We have the value of constant $k = 0.004297$. Applying this value of k in equation (2) and multiplying by 10⁴, we get the value of r in microns.

A-3.6.3 Stoke's law is applicable to angular and cubical particles of the same mass as spherical particles. For calculating the grain size as width (or edge length) of a cube of the same volume as sphere of radius r , the width of the cube may be expressed as follows:

Width of the cube, $C = 1.612 r$.

NOTE — This width of the cube shall be adopted for expressing the results of test for particle size distribution in a clay.

A-3.6.4 Determine the radius r of the particles of the clay sample by using equation (2) (see A-3.6.1), and appropriate values for viscosity and density of water at the temperature of test (see Table 3) and convert into width of cube (see A-3.6.3) and plot a smooth graph with C as the abscissa and percentage of mass M (see A-3.5) finer than the corresponding size as the ordinate. Finally, construct a histogram to find out the particle size distribution for the specified size ranges. A model calculation of particle size distribution is illustrated in Table 3 and a graph and histogram based on data given in it are drawn in Fig. 2 for guidance.

Table 3 Model Calculation for the Determination of Particle Size Distribution of Clay
(Clause A-3.6.4)

Time of Drawing Sample from the Start of the Test,	Radius of Particles,	Width of Cube,	Mass of Empty Dish,	Mass of Empty Dish and Sample,	Mass of Sample,	Corrected ¹⁾ Mass of Sample,	Under Size, percent cumulative
s	microns	microns	g	g	g	g	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
120	17.54	28.27	35.026 2	35.128 6	0.102 4	0.097 1	97.1
300	10.98	17.70	38.065 9	38.167 0	0.101 1	0.095 8	95.8
600	7.69	12.40	39.151 6	39.252 5	0.100 9	0.095 6	95.6
1 800	4.39	7.08	41.199 7	41.199 7	0.093 4	0.088 1	88.1
3 600	3.07	4.95	37.026 5	37.115 7	0.089 2	0.083 9	83.9
7 200	2.15	3.47	21.049 5	21.132 4	0.082 9	0.077 6	77.6
14 400	1.50	2.42	25.223 5	25.298 8	0.075 3	0.070 0	70.0
21 600	1.21	1.95	20.461 2	20.532 0	0.070 8	0.065 5	65.5
86 400	0.60	0.97	40.013 6	40.017 2	0.057 6	0.052 3	52.3

¹⁾ Value after subtracting 0.005 3 g, mass of electrolyte in 10 ml of suspension (see A-3.5), whereas theoretical mass of sample in 10 ml of suspension = 0.10 g.

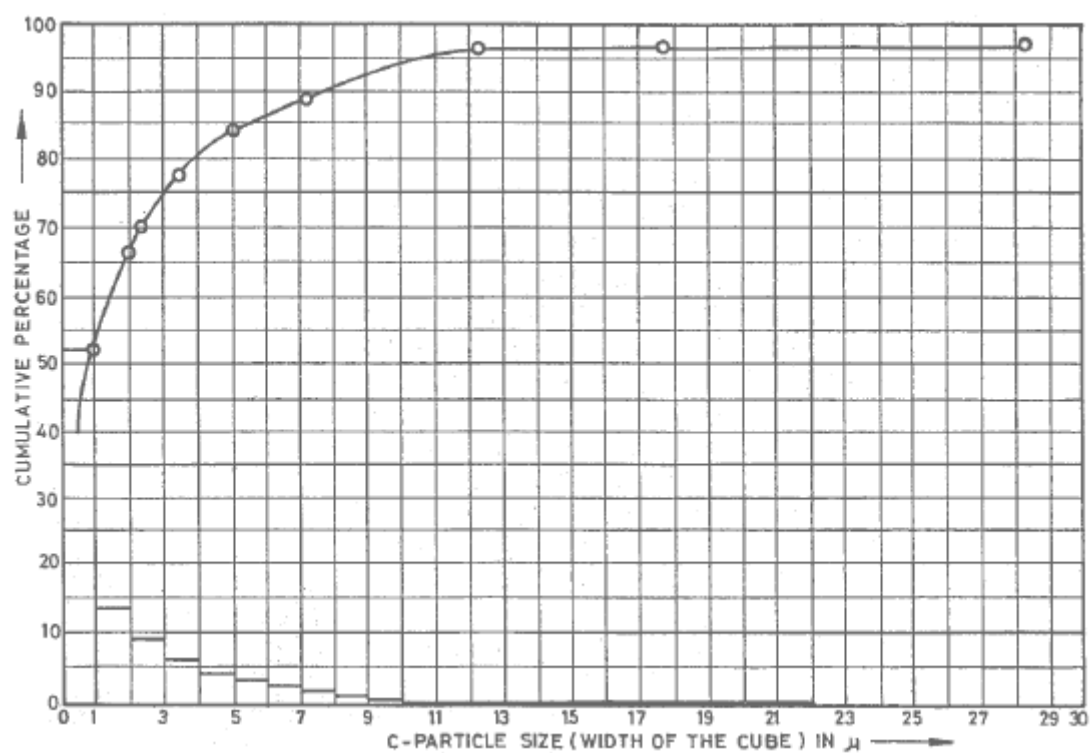


FIG.2 MODEL GRAPH AND HISTOGRAM BASED ON DATA GIVEN IN TABLE 3

A-4 PLASTICITY BY HAND FEEL TEST

A-4.1 Apparatus

A-4.1.1 Spatula — One.

A-4.1.2 Porcelain Basin — One [conforming to IS 2837 (Part 2)].

A-4.2 Procedure

Dry thoroughly about 500 g of clay at a temperature of 70 °C and crush to pass through 250-micron IS sieve. Work up sieve clay with water by adding small quantities of water to a plastic consistency and thoroughly wedge and knead by hand. Allow it to age for 24 h keeping it covered with wet cloth during the period. After 24 h, knead the plastic mass again and pug it well by further additions of small water until proper working consistency of either extrusion or moulding into bars is obtained (A-5.3). Take a portion of the clay mass. Work it over a dry and smooth glass plate by hand. If it slides over the glass plate very smoothly without developing any crack on the clay mass, it may be termed 'very good'. If it works otherwise, it may be termed as per the feeling of the worker.

A-5 DETERMINATION OF WATER OF PLASTICITY

A-5.1 Outline of the Method

The water content of clay at the point of maximum workability is determined. This, when expressed as a percentage of oven-dried clay, gives the value for water of plasticity.

A-5.2 Apparatus

A-5.2.1 Spatula

A-5.2.2 Porcelain Basin

A-5.2.3 Burette — 50-ml capacity.

A-5.2.4 Balance — Accurate up to 0.01 g.

A-5.3 Procedure

A-5.3.1 Crush about 150 g of the clay sample (*see C-5*) to pass through a 250 micron IS sieve. Work up the sieved clay with distilled water, adding a small quantity at a time from a burette to a soft plastic consistency and thoroughly wedge and knead by hand. Cover with a wet cloth and allow to age for 24 h. Again knead the plastic mass and pug, adding small quantity of water as necessary, until the mass attains working consistency for either extrusion or moulding into bars. Divide the mass into three equal portions rounding the edges and corners to prevent loss of material in handling. Place each portion on a separate tared watch glass and weigh immediately to the nearest 0.01 g.

A-5.3.2 Then dry them for 4 h at 70 ± 2 °C and finally for 12 h and at 110 ± 5 °C. Cool in a desiccator and weigh each to the nearest 0.01 g.

A-5.4 Calculation

A-5.4.1 Water of plasticity, percent by mass =

$$\frac{M - M_1}{M_1} \times 100$$

where

M = mass of the plastic clay mass (A-5.3.1), in g,
and

M_1 = mass of the dried clay mass (A-5.3.2), in g.

A-5.4.2 Report the average of three results. Results of test on each plastic mass shall agree within 0.5 percent by mass of the average value. If results of each test do not agree within the tolerance limit, they shall be rejected and the tests shall be repeated.

A-6 DETERMINATION OF ATTERBERG NUMBER

A-6.1 Principle

The difference in water contents between the lower limit of mobility (liquid limit) and the rolling limit (plastic limit) of the clay is determined. The value thus obtained is the Atterberg number of the clay.

A-6.2 Apparatus

A-6.2.1 Porcelain Basin — 110 mm in diameter.

A-6.2.2 Spatula

A spatula having a blade about 75 mm in length and about 20 mm in width.

A-6.2.3 Liquid Limit Device

A mechanical device consisting of a hard rubber base and a brass cup with carriage so constructed as to allow the cup to be moved up and down by means of a crank. A sketch of the apparatus is given in Fig. 3.

A-6.2.4 Grooving Tool

Grooving tool of the shape shown in Fig. 4. The blade of the tool shall have a width of 1 cm.

A-6.2.5 Ground — Glass plate.

A-6.2.6 Balance — Accurate to 0.01 g.

A-6.3 Determination of Liquid Limit

A-6.3.1 Sample Preparation

Crush about 100 g of the clay sample (*see C-5*) to pass through 250-micron IS sieve and dry at 110 ± 5 °C for 1 h.

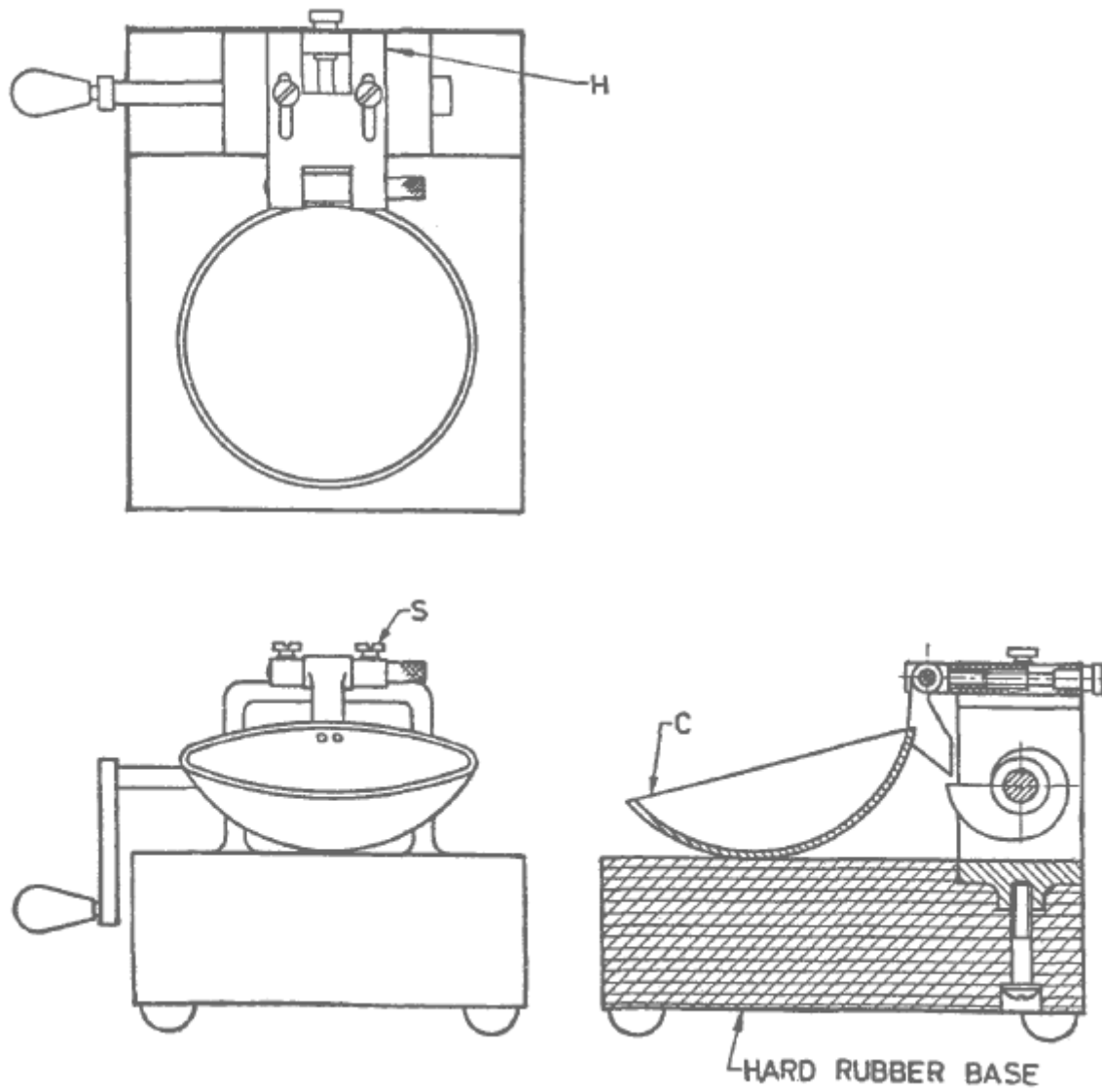


FIG. 3 MECHANICAL LIQUID LIMIT DEVICE



FIG. 4 GROOVING TOOL

A-6.3.2 Adjustment of the Mechanical Device

Adjust the height with the help of a gauge 1 cm in width to which the cup is fitted so that the point on the cup that comes in contact with the base is exactly 1 cm above the base. Secure the adjustment plate *H* by tightening the screw *S*.

A-6.3.3 Procedure

A-6.3.3.1 Mix the clay sample (A-6.3.1) in the porcelain basin thoroughly with 10 to 15 ml of distilled water by kneading and chopping with a spatula. Add water further in increments of 1 to 3 ml. thoroughly mix each increment of water before adding the next increment. When sufficient water has been added to produce a proper consistency, cover the plastic mass with a wet cloth and allow to age for 24 h. Again knead the plastic mass and then place the clay mass in the cup above the resting spot. Squeeze it down and spread it evenly with the spatula, care being taken to prevent entrapment of air bubbles. Level the clay mass with the spatula and simultaneously trim it to a depth of 1 cm at the point of maximum thickness. Return the trimmings to the basin. Divide the clay mass in the cup by firm strokes of the grooving tool along the diameter through the centre line of the cam follower so that a clean sharp groove of proper dimensions is formed. To avoid tearing of the sides of the grooves or slipping of the clay mass on the cup, up to six strokes, from front to back or from back to front, shall be permitted. Each stroke shall penetrate a little deeper until the last stroke from back to front scrapes the bottom of the cup clean. Make the groove with as few strokes as possible. Lift and drop the cup by turning the crank at the rate of two revolutions per second, until the two halves of the clay mass come in contact at any point along a distance of 1.25 cm on the line of the groove. Record the number of drops required to close the groove along a distance of 1.25 cm.

A-6.3.3.2 Remove a portion of the clay mass approximately of the width of the spatula that just followed and place in a tared vessel. Weigh and then dry at $110 \pm 5^\circ\text{C}$ in an air oven and cool in a desiccator. Weigh after cooling. Record the loss in mass due to drying as the mass of water necessary to attain proper consistency.

A-6.3.3.3 Repeat the operation at least twice, adding more water each time to bring the clay to a more mobile condition. Thus, values above and below 25 are obtained for the number of drops required to close the groove.

A-6.3.4 Calculation

A-6.3.4.1 Water content, percent by mass = $\frac{M_1}{M_2} \times 100$

where

M_1 = mass of water (A-6.3.3.2), in g, and

M_2 = mass of the oven-dried clay, in g.

A-6.3.4.2 Flow curve

Plot a flow curve on a semi-logarithmic graph with the water content as abscissa on the arithmetical scale and the corresponding number of strokes as ordinate on the logarithmic scale. The curve shall be a straight line drawn as nearly as possible through the three points.

A-6.3.4.3 Liquid limit

Take the water content corresponding to the intersection of the flow curve with the 25 drop ordinate as the liquid limit of clay. Report the liquid limit value to the nearest whole number.

A-6.4 Determination of Plastic Limit

A-6.4.1 Crush about 10 g of the clay sample (*see C-5*) to pass through 250 micron IS sieve and thoroughly mix with sufficient quantity of water to give a plastic mass which can be easily shaped into a ball. Cover the plastic mass with a wet cloth and allow to age for 24 h. Again knead the plastic mass and then roll it between the fingers and the ground glass plate into a thread of uniform diameter throughout its length. The rate of rolling shall be between 80 and 90 strokes per minute, counting a stroke as the complete motion of the hand forward and back to the starting position again. When the diameter of the thread becomes 0.32 cm, break the thread into six or eight pieces. Squeeze the pieces together between the thumbs, knead and roll again. Continue this process of alternate rolling, gathering together, kneading and re-rolling, until the thread crumbles under the pressure required for rolling and cannot be rolled into a thread having a diameter of 0.32 cm. weigh the crumbled pieces of the thread together. Dry them in an air-oven at a temperature of $110 \pm 5^\circ\text{C}$, cool in a desiccators and weigh. Record the loss in mass of the water necessary to attain that consistency.

A-6.4.2 Plastic Limit

Calculate the plastic limit, expressing the water content as percentage of oven dry clay as follows:

$$\text{Plastic limit, percent} = \frac{M_1 - M}{M} \times 100$$

where

M_1 = mass of the crumbled pieces of thread, in g;
and

M = mass of the crumbled pieces of thread after drying, in g.

A-6.5 Atterberg Number

Calculate the difference in water content of clay between its liquid limit at 25 drops (obtained in A-6.3.4.3) and its plastic limit (obtained in A-6.4.2). This value thus obtained is the Atterberg number.

A-7 DETERMINATION OF LOSS ON IGNITION

A-7.1 Procedure

A-7.1.1 Take about 50 g of the material in china dish and heat to constant weight at 105 ± 2 °C. Cool it in a desiccator and keep for subsequent tests.

A-7.1.2 Transfer 1 g of the material from the sample in **A-7.1.1** to a weighed platinum crucible. Introduce it into a muffle furnace and slowly raise the temperature to $1\,000 \pm 50$ °C. After about 30 min, remove the crucible and cool in a desiccator and weigh. Repeat ignition and cooling to obtain constant mass.

A-7.2 Calculation

$$\text{Loss on ignition, percent} = \frac{M_1 - M_2}{M_1} \times 100$$

where

M_1 = mass of dried material before heating in muffle furnace, in g; and

M_2 = mass of material after heating in muffle furnace and cooling, in g.

A-8 DETERMINATION OF ALUMINA

A-8.1 Outline of the Method

Aluminium (also iron and titanium, when present) is complexed quantitatively with EDTA by boiling with an excess of the reagent. The excess EDTA is back titrated with standard zinc solution at pH about 5.3 using xylenol orange indicator. The aluminium EDTA complex (also titanium-EDTA complex, if present) on boiling with ammonium fluoride liberate EDTA which, when titrated with standard zinc solution, gives the amount of aluminium present in the solution. Due correction for titania is also carried out.

A-8.2 Reagent

A-8.2.1 EDTA Solution — (0.025 M)

Dissolve 9.31 g of disodium salt of ethylene diamine tetra-acetic acid dihydrate ($\text{C}_{10}\text{H}_{14}\text{N}_2\text{Na}_2\text{O}_8 \cdot 2\text{H}_2\text{O}$) in water and dilute to 1 000 ml.

A-8.2.2 Methyl Orange

Dissolve 0.05 g of methyl orange in 100 ml of water.

A-8.2.3 Dilute Ammonia — (1 : 5)

Dilute 25 ml of concentrated ammonia (R.D. 0.90) to 150 ml.

A-8.2.4 Acetate Buffer — (pH 5.3)

Dissolve 21.5 g of sodium acetate ($\text{CH}_3\text{COONa} \cdot 3\text{H}_2\text{O}$) in 300 ml of water containing 2 ml of glacial acetic acid and dilute to 1 l.

A-8.2.5 Standard Aluminium Oxide Solution — Weigh 0.529 3 g of aluminium metal (99.9 percent purity) into a beaker containing 40 ml of dilute hydrochloric acid (1 : 1) and small drop of mercury.

Heat the beaker over a water-bath. Transfer the solution to a 1 000-ml volumetric flask and make up to the mark. One ml of this solution is equivalent to 1.0 mg of aluminium oxide (as Al_2O_3).

NOTE — Mercury will not dissolve and may be removed while transferring the solution to 1 000 ml volumetric flask.

A-8.2.6 Standard Zinc Solution — 0.025 M.

Dissolve 5.484 5 g of zinc acetate [$\text{Zn}(\text{CH}_3\text{COO})_2 \cdot 2\text{H}_2\text{O}$] in 2 ml of glacial acetic acid and 25 ml of acetate buffer (**A-8.2.4**) and dilute to 1 l in a volumetric flask. Find out the equivalent Al_2O_3 in g/ml from the procedure given in **A-8.3** taking 20 ml of standard aluminium solution (**A-8.2.5**).

A-8.2.7 Xylenol Orange — Dissolve 0.1 g of xylenol orange in 100 ml of water containing two drops of dilute hydrochloric acid (1:1).

A-8.2.8 Ammonium Fluoride — Dissolve 20 g of ammonium fluoride in 100 ml of water. Add 3 drops of xylenol orange (**A-8.2.7**) and then dilute hydrochloric acid (1 : 9) drop wise till the colour changes to yellow.

A-8.3 Preparation of the Sample Solution

Weigh accurately about 2 g of the dried material in a platinum dish (*see* **A-7.1**). Moisten the sample with 5 ml of water. Add 3 ml of dilute sulphuric acid and 20 ml of hydrofluoric acid and evaporate to dryness on the sand bath in a fume cupboard, taking care to avoid spurting. Cool and repeat the process of evaporation twice with another 10 ml of hydrofluoric acid each time. Cool, add 2 ml of dilute sulphuric acid and evaporate as before. Heat the dry residue cautiously until fumes of sulphur trioxide cease. Ignite the residue at 1 000 °C for 5 min and cool. Fuse the residue with 3 g of anhydrous sodium carbonate, cool the fused mass and dissolve it in 25 ml of dilute hydrochloric acid and dilute with water to 250 ml in a volumetric flask. Reserve the solution for determination of iron and titania.

A-8.4 Procedure

Transfer 100 ml of the solution prepared in **A-8.3** to a 500 ml conical flask. Add sufficient EDTA solution to provide an excess of at least 5 ml over the expected amount of alumina and iron (1 ml of 0.025 M EDTA = 1.25 mg Al_2O_3 approximately). Add 2 to 3 drops of methyl orange and then add dilute ammonia drop wise until the colour changes from red to yellow. Add 5 ml of acetate buffer and about 25 ml of water, and heat to boiling for 5 min. Cool, add 5 ml of buffer solution and titrate with standard zinc solution using 5 to 6 drops of xylenol orange indicator. The end point is indicated by a clear change from yellow to deep orange colour.

Add 10 ml of ammonium fluoride solution and heat to boiling for 5 min. Cool, add 5 ml of buffer solution and titrate the liberated EDTA with standard zinc solution.

NOTE — If titania content is above 0.5 percent, it may affect the sharpness of the end point.

A-8.5 Calculation

Alumina, percent by mass =

$$\frac{V \times F}{M} \times 100 - (0.637 \times D)$$

where

V = volume of standard zinc solution required for the titration of liberated EDTA, in ml;

F = equivalent, Al_2O_3 of standard zinc solution, in g/ml;

M = mass of the sample represented by the aliquot taken (A-8.4), in g; and

D = percent of TiO_2 in the sample, the value having been obtained by photometric determination (see A-10.4).

A-9 DETERMINATION OF IRON OXIDE

A-9.1 Outline of the Method

The orange-red complex, produced by ferrous iron on addition of *o*-phenanthroline, is determined photometrically at approximately 510 nm.

A-9.2 Reagents

A-9.2.1 Dilute Sulphuric Acid — 1 : 1 (v/v).

A-9.2.2 Hydrofluoric Acid — 40 percent.

A-9.2.3 Dilute Hydrochloric Acid — 1 : 1 (v/v).

A-9.2.4 Tartaric Acid Solution — 10 percent (m/v) in water.

A-9.2.5 Hydroxylamine Hydrochloride Solution

Dissolve 1 g of the reagent in water and dilute to 100 ml.

A-9.2.6 *o*-Phenanthroline Solution

Dissolve 1 g of *o*-phenanthroline monohydrate in 90 ml of water by gentle heating and constant stirring. Cool and dilute to 100 ml with water.

A-9.2.7 Acetate Buffer Solution

Dissolve 21.5 g of sodium acetate ($\text{CH}_3\text{COONa} \cdot 3\text{H}_2\text{O}$) in 300 ml of water containing 2 ml of glacial acetic acid and dilute to 1 000 ml with water.

A-9.2.8 Standard Iron Solution

Dissolve 7.02 g of ammonium ferrous sulphate $[(\text{NH}_4)_2\text{SO}_4 \cdot \text{FeSO}_4 \cdot 6\text{H}_2\text{O}]$ in water containing 10 ml of concentrated sulphuric acid and dilute with water to

1 000 ml. Dilute 20 ml of this solution to 1 000 ml with water just before use. 1 ml of this diluted solution is equivalent to 0.02 mg of iron (as Fe).

A-9.3 Preparation of the Blank Solution

Prepare the blank solution following the procedure and using the same quantities of reagents given in A-8.3 but without the material and dilute the solution with water to 250 ml in a volumetric flask.

A-9.4 Procedure

A-9.4.1 Transfer 5 ml aliquot of the sample solution prepared in A-8.3 to a 50 ml volumetric flask. Add 2 ml of tartaric acid solution and 2 ml of hydroxylamine hydrochloride solution. Stir and add 5 ml of *o*-phenanthroline solution followed by 10 ml of acetate buffer solution. Mix the contents, allow to stand for 15 min and dilute with water up to the mark.

A-9.4.2 Transfer 0, 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10 ml of the standard iron solution to eleven 50 ml volumetric flasks. Add 5 ml of the blank solution in place of the sample solution and the same quantities of reagents as in A-9.4.1 to each of the volumetric flasks and dilute up to the mark with water.

A-9.4.3 Transfer suitable aliquots of the solutions prepared in A-9.4.2 to the absorption cell and take photometric readings at 510 nm, and plot a curve showing the amount of iron (as Fe) in mg against the readings. Then transfer an aliquot of the sample solution prepared in A-9.4.1 to the absorption cell and record the photometric reading.

A-9.5 Calculation

Convert the reading obtained with the sample solution in A-9.4.3 into mg of iron, using the calibration curve and calculate the percentage of iron oxide as follows:

$$\text{Iron oxide (as Fe}_2\text{O}_3\text{), percent by mass} = \frac{M}{M_1} \times 0.1429$$

where

M = mass of iron found in the sample solution (A-9.4.3), in mg; and

M_1 = mass of the material represented by 5 ml of the aliquot taken in A-9.4.1, in g.

A-10 DETERMINATION OF TITANIUM DIOXIDE (TiO_2)

A-10.1 Outline of the Method

The yellow coloured complex, produced in acid solution of the sample by the addition of hydrogen peroxide, is determined photometrically at approximately 410 nm.

A-10.2 Reagents

A-10.2.1 Dilute Sulphuric Acid — 1 : 1 (v/v).

A-10.2.2 Phosphoric Acid

Add 400 ml of phosphoric acid (R.D. 1.75) to 500 ml of water, cool and dilute to 1 l.

A-10.2.3 Hydrogen Peroxide — 20 volumes.**A-10.2.4 Standard Titanium Dioxide Solution**

Weigh accurately 3.680 g of potassium titanyl oxalate $[K_2TiO_2(C_2O_4)_2 \cdot 2H_2O]$. Transfer to a boiling flask, add 8 g of ammonium sulphate and 100 ml of concentrated sulphuric acid. Gradually heat the mixture to boiling and boil for 10 min. Cool, pour the solution into 750 ml of water, and dilute to 1 000 ml in a volumetric flask. One ml of this solution is equivalent to 0.5 mg of titanium dioxide (as TiO_2).

A-10.3 Procedure

A-10.3.1 Transfer 25 ml of the prepared solution (A-8.3) to a 100-ml volumetric flask. Add 2.5 ml of dilute sulphuric acid, 5 ml of phosphoric acid, and 5 ml of hydrogen peroxide. Make up the volume to the mark with water and mix.

A-10.3.2 Calibration Curve

Transfer 25 ml each of the blank solution (A-9.3) to eleven 100 ml volumetric flasks and 0, 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10 ml respectively of the standard titanium dioxide solution using the same quantity of reagents as in A-10.3.1. Make up the solution up to the mark. Take the required aliquots of these solutions in the absorption cell, one at a time, and plot a curve showing optical densities of solution at 410 nm against the amount of titanium dioxide in milligrams present in each.

A-10.3.3 Take an appropriate aliquot of the solution prepared in A-10.3.1 in the absorption cell and measure its optical density at 410 nm. From the calibration curve, note the amount of titanium dioxide in milligrams present in it.

A-10.4 Calculation

Titanium dioxide, percent by mass = $\frac{M_1}{M} \times 0.1$

where

M_1 = mass of titanium dioxide content present in the aliquot taken for the test (A-10.3.3), in mg; and

M = mass of the material present in the aliquot taken for the test (A-10.3.1), in g.

A-11 DETERMINATION OF DRY LINEAR SHRINKAGE**A-11.1 Outline of the Method**

Dry linear shrinkage of clay is determined by measuring the decrease in one dimension of a plastic mass upon drying and expressing it as percentage on plastic basis.

A-11.2 Apparatus**A-11.2.1 Mould**

A collapsible brass mould with internal dimensions of 25 mm × 25 mm × 120 mm suitable for forming the test specimen of that size.

A-11.2.2 Divider**A-11.2.3 Diagonal Scale****A-11.2.4 Air Oven**

Provided with thermostat and capable of drying clay at 110 ± 5 °C.

A-11.3 Procedure

A-11.3.1 Take a portion of clay as prepared in A-5.3 and again knead thoroughly. Coat the inside of the brass mould evenly with a thin layer of petroleum jelly or kerosene oil or light machine oil. Press a lump of the plastic mass into the mould. Take care to avoid entrapping any air. Scrap off any excess clay with a straight-edged spatula from the top of the mould and finally wipe off any adhering clay. Make the surface of clay smooth and mark two reference points approximately 100 mm apart. Measure the distance between the two points accurately to second place of decimal with divider and diagonal scale. Prepare five such test specimens.

A-11.3.2 Carefully release the test specimens from the mould and allow to dry slowly under a wet cloth for 48 h. Wipe off the petroleum jelly adhering to the specimen. Air-dry the specimen for another 48 h at room temperature, occasionally turning sides of the test specimens to expose new surfaces for evaporation.

A-11.3.3 Alternatively, prepare the test specimen by pugging two or three times the plastic mass as prepared in A-5.3 in a de-airing pug mill and extrude clay specimens in the form of either cylindrical bar or rectangular bar having cross-sectional area of about 150 mm² and 150 mm in length. Place the extruded test specimens on a lightly oiled glass plate and then mark two reference points approximately 100 mm apart. Measure the distance between the two points accurately to second place of decimal with divider and diagonal scale. Prepare five such test specimens. Do not disturb the test specimens until they attain leather hard condition during drying.

NOTE — A vacuum of not less than 700 mm of mercury shall be maintained during pugging operation.

A-11.3.4 Place the test specimens in the air oven and dry them at 110 ± 5 °C for 24 h. Remove the test specimens from the oven and keep in a desiccator to cool. Measure the distance between the two reference points, accurate to second place of decimal.

A-11.4 Calculation — Calculate the dry linear shrinkage as follows:

$$\text{Dry linear shrinkage, percent} = \frac{L_p - L_d}{L_p} \times 100$$

where

L_p = distance between the two reference points on the plastic mass, in mm; and

L_d = distance between the two reference points on the dry mass, in mm.

NOTE — Round off the calculated values to the second place of decimal.

Report the average of results of test for five test specimens. Result of test on each bar shall agree within ± 0.5 percent of the average value. If any result does not agree within the tolerance limits, it shall be rejected and the test shall be repeated.

A-12 DETERMINATION OF DRY MODULUS OF RUPTURE

A-12.1 Outline of the Method

Modulus of rupture is determined using extruded cylindrical or rectangular bars made out of the clay and dried carefully to avoid warping, cracking, etc.

A-12.2 Apparatus

A-12.2.1 Testing Machine

Any suitable testing machine having the following essential features may be used:

- Two steel knife-edges rounded to a radius of 6.35 mm or more and approximately 80 mm apart for supporting the test specimen; and
- A steel knife-edge also rounded to a radius of 6.35 mm or more for applying load at midpoint between the two supporting knife-edges directly at a uniform rate of loading not exceeding 44 N/min.

A-12.3 Procedure

A-12.3.1 Crush about 5 kg of the clay sample (see C-5) to pass through 250-micron IS sieve. Work up the sieved clay with distilled water to a soft plastic consistency and thoroughly wedge and knead by hand. Cover with a wet cloth and allow to age for 24 h. Again knead the plastic mass and pug in a de-airing pug mill, adding small quantity of water as necessary, until the mass attains working consistency for extrusion. Finally, prepare at least 10 cylindrical or rectangular specimens measuring about 150 mm² cross-sectionally, the length being adjusted such that after drying, the ends extend on either side of the supporting knife-edges at least 10 mm.

NOTE — A vacuum of not less than 700 mm of mercury shall be maintained during pugging operation.

A-12.3.2 Place the extruded test specimens on a lightly oiled glass plate, cover with a wet cloth and allow to dry for 24 h at room temperature. Then dry for 4 h at 70 ± 2 °C and finally for 24 h at 110 ± 5 °C and cool in a desiccator.

NOTE — Due precautions shall be observed in the forming and drying of the test specimens so that they are straight and do not show warpage greater than one percent of their overall length. The bars shall be checked from time to time during drying for straightness and before they stiffen corrective straightening may be obtained by rotating the bars so that drying occurs from another surface region. Bars having flaws, warpage or voids, shall be rejected.

A-12.3.3 Remove a test specimen from the desiccator and immediately place on the supporting knife-edges of the testing machine so that the ends extend on either side by at least 10 mm. Apply the load at right angles to the specimen and midway between the supporting knife-edges at a uniform rate of not exceeding 4.4 N/min until failure occurs. Note the load which breaks the test specimen, measure the diameter in case of cylindrical specimen or the breadth and depth in case of rectangular specimen at the point of breaking, nearest to 0.03 mm, at least at three points around the circumference or perimeter at the cross-section and calculate the average.

A-12.3.4 Carry out this test on at least 10 specimens.

A-12.4 Calculation

Calculate the modulus of rupture for each test specimen as follows:

a) For cylindrical specimen, $M = \frac{8PL}{\pi d^3}$

b) For rectangular specimen, $M = \frac{1.5PL}{BD^2}$

where,

M = modulus of rupture; in MPa;

P = load causing rupture, in N;

L = distance between the supporting edges, in mm;

d = diameter of the test specimen, in mm;

B = breadth of the test specimen, in mm; and

D = depth of the test specimen, in mm.

Report the average of result of test for 10 test specimens. The results of test on each test specimen shall agree within ± 5 percent of the average value of results. If any result does not agree within the tolerance limit, it shall be rejected and another test specimen shall be tested.

A-13 DETERMINATION OF MATURITY

A-13.1 Outline of the Method

Discs of china clay are fired to a temperature of 1 200 °C and the water absorption is determined by soaking the fired discs in water.

A-13.2 Apparatus

A-13.2.1 Balance — Accurate to 0.01 g.

A-13.2.2 Air-Oven

Capable of maintaining a temperature of 105 to 110 °C.

A-13.2.3 Electric Muffle Furnace

Capable of maintaining a temperature of 1 200 °C.

A-13.3 Preparation of Test Sample

A-13.3.1 Crush about 500 g of the clay sample (see C-5) to pass through 250-micron IS sieve. Work up the sieved clay with distilled water, adding a small quantity at a time from a burette to a soft plastic consistency and thoroughly wedge and knead by hand. Cover with a wet cloth and allow to age for 24 h. Again knead the plastic mass and pug adding small quantity of water, as necessary, until the mass attains consistency for moulding.

A-13.3.2 Prepare discs about 25 mm in diameter and 10 mm in thickness by pressing by hand the china clay mass prepared in A-13.3.1 in steel moulds. Cover the discs with a wet cloth and allow to dry for 24 h at room temperature. Then dry them for 4 h at 70 ± 2 °C and finally for 12 h at 110 ± 5 °C.

A-13.4 Procedure

A-13.4.1 Place the test pieces prepared in A-13.3.2 into the electric furnace. Raise the temperature at the rate of 75 °C per hour till temperature reaches 1 200 °C. At this stage, stop raising the temperature and soak for 30 min maintaining the temperature at 1 200 °C and finally switch off the furnace. Allow the furnace to cool to room temperature. Take the test pieces out and cool in a desiccator. Examine the test pieces for fired colour.

A-13.4.2 Weigh accurately five individual test pieces nearest to 0.05 g. Immerse them in distilled water in a beaker taking care that they do not touch each other and also do not touch the sides or bottom of the beaker. Boil for 5 h and then allow to soak in the same water for 24 h keeping the pieces immersed all the time.

A-13.4.3 Next day, lightly blot each piece with moist linen or cotton cloth to remove excess water from their surface and immediately weigh to the nearest 0.05 g.

A-13.5 Calculation

Calculate water absorption as a measure of maturity as follows:

$$\text{Water absorption, percent by mass} = \frac{M_1 - M}{M} \times 100$$

where

M_1 = mass of the test piece soaked in water (A-13.4.3), in g; and

M = mass of the dry test piece (A-13.4.2), in g.

Report the average of results of test for five test pieces. Results of test on each test piece shall agree within 0.5 percent of the average value. If any result does not agree with the tolerance limits, it shall be rejected and the test shall be repeated.

A-14 DETERMINATION OF APPARENT POROSITY**A-14.1 Principle**

Determination of apparent porosity is based on determination of total volume of open pores in the bulk volume of the specimen.

A-14.2 Procedure

A-14.2.1 Weigh accurately five individual test pieces, prepared after heating at 1 200 °C as in A-13.3.1, nearest to 0.02 g (D). Immerse them in distilled water in a beaker taking care that they neither touch each other nor the sides or bottom of the beaker. Boil for 2 h and allow to soak in the same water overnight with pieces immersed all the time.

A-14.2.2 Next day, take the suspended weight of the individual test pieces kept immersed, in a physical balance nearest to 0.02 g (S), taking care that it does not touch the sides or bottom of the beaker or the balance. Then lightly blot each piece with moist linen or cotton cloth to remove the excess water from their surfaces and immediately weigh to the nearest 0.02 g (W).

A-14.3 Calculation

$$\text{Apparent porosity, percent by mass} = \frac{W - D}{W - S}$$

where

W = mass of the test piece soaked in water, in g;

S = suspended mass of the water soaked test piece, in g; and

D = mass of the dry test piece, in g.

A-14.4 Result

Report the average of test for five test pieces. Results of test on each piece shall agree within ± 1.0 percent. If any result does not agree with the tolerance limits, it shall be rejected and the test shall be repeated.

A-15 DETERMINATION OF TOTAL LINEAR SHRINKAGE**A-15.1 Principle**

The decrease in one dimension of a clay specimen in plastic state, when dried and heated to the required temperature, is measured.

A-15.2 Procedure

Take five test specimens as prepared and duly marked in A-11.2.1 to A-11.2.3. Place them in a suitable

furnace, and heat to 1 200 °C (A-13.4.1). Remove the test specimens and cool in a desiccator. Measure the distance between the two reference points with a vernier caliper accurately to the second place of decimal.

A-15.3 Calculation

A-15.3.1 Calculate the total linear shrinkage as follows:

$$\text{Total linear shrinkage, percent} = \frac{L_p - L_f}{L_p} \times 100$$

where

L_p = distance between the reference points on the specimen in plastic state, in mm; and

L_f = distance in mm between the two reference points on the fired specimen, in mm.

NOTE — Round off to the nearest second place of decimal.

A-15.3.2 Report the average of five test specimens.

A-16 METHOD OF DETERMINATION OF PYROMETRIC CONE EQUIVALENT IN ORTON

A-16.1 Objective of Test

The object of this test is to determine the PCE value of china clay by comparing the test cones prepared from the material under test with standard pyrometric cones heated in a suitable furnace at a definite rate of rise of temperature.

A-16.2 Apparatus

A-16.2.1 *Furnace* — Gas-fired, capable of maintaining a natural or oxidizing atmosphere.

A-16.3 Preparation of Test Cones

Take about 200 g of the dry sample and grind to pass through 150-micron IS sieve, avoiding excessive reduction of size. Mix thoroughly with sufficient alkali-free dextrin, glue or starch solution in water and form into test cones in a metal mould, in the shape of tetrahedron measuring 8 mm on the sides of the base and 25 mm high. Dry these cones slowly.

A-16.4 Procedure

A-16.4.1 Mount the test cones along with Orton standard pyrometric cones covering the appropriate range (see Table 1), around the outer edge of a fireclay plaque so that their bases are embedded approximately 3 mm deep and one of the faces is inclined towards the centre of the plaque at an angle of 82° with the horizontal.

A-16.4.2 Carry out heating of the mounted cones in the furnace at a uniform rate of 150 °C per hour until a temperature of 1 000 °C is reached. Then, reduce this rate to 120 °C per hour and continue heating till the deformation takes place. Avoid reducing conditions in

the furnace during heating operation. Softening of the cones is indicated by the top bending over the tip of the cone touching the plaque surface.

A-16.4.3 Report the fusibility of the material in terms of the Orton standard pyrometric cone which most nearly corresponds in time of complete bending with the test cone.

A-17 DETERMINATION OF CALCIUM OXIDE

A-17.1 Outline of the Method

In an aliquot of the sample solution, metallic oxide (R_2O_3) group elements are marked by triethanolamine, and calcium is titrated with EDTA solution using Patton and Reader (P & R) indicator.

A-17.2 Reagents

A-17.2.1 *Concentrated Nitric Acid* — See IS 264.

A-17.2.2 *Perchloric Acid* — 70 percent (m/m).

A-17.2.3 *Hydrofluoric Acid* — 40 percent (m/m) (see IS 10332).

A-17.2.4 *Concentrated Hydrochloric Acid* — See IS 265.

A-17.2.5 *Triethanolamine Solution* — 30 percent (v/v). Dilute 60 ml of triethanolamine to 200 ml.

A-17.2.6 *Sodium Hydroxide Solution* — 5N approximately. Dissolve 100 g of sodium hydroxide in water, cool and dilute to 500 ml and store in a polythene bottle.

A-17.2.7 *Patton and Reader (P & R) Indicator* — Mix by grinding together 0.1 g of P & R indicator and 30 g of sodium chloride. About 0.2 g of the mixture is required for each titration.

A-17.2.8 *Standard EDTA Solution* (0.01 M) — Dissolve 9.31 g of disodium ethylene-diamine tetra acetate, dihydrate ($C_{10}H_{14}N_2Na_2O_8 \cdot 2H_2O$) in water and dilute to 1 l. Transfer 100 ml of the solution to a 250 ml volumetric flask and dilute with water up to the mark. Standardize against the standard calcium solution (see A-17.2.9) using P & R indicator.

A-17.2.9 *Standard Calcium Solution* — Dissolve 1.784 8 g of calcium carbonate dried at 150 °C in a slight excess of hydrochloric acid, boil to expel carbon dioxide, cool and dilute to 1 000 ml. 1 ml of this solution is equivalent to 1 mg of calcium oxide (as CaO).

A-17.3 Procedure

A-17.3.1 Solution of the Sample

Weigh accurately about 1 g of the test sample in a platinum dish. Add 5 ml of concentrated nitric acid, 5 ml of perchloric acid and about 10 ml of hydrofluoric

acid. Cover the dish with a lid. Allow the reaction to proceed for at least 15 min, then remove the lid and evaporate the mixture to dryness on a sand bath in a fume cupboard, taking care to avoid spurting. Cool, add 5 ml of perchloric acid, rinse the lid and sides of the dish with water and again evaporate carefully to dryness. To the cool, dry residue, add 2 ml of concentrated hydrochloric acid and about 15 ml of water. Digest on a steam bath for 10 min, cool, filter if necessary and dilute the solution with distilled water to 250 ml in a volumetric flask. Store the solution in a polythene bottle.

A-17.3.2 Determination of Calcium Oxide

Pipette 50 ml of the solution into a 250 ml conical flask. Add 10 ml of triethanolamine solution, 5 ml of sodium hydroxide solution drop wise while shaking the

solution, and then add 0.2 g of P & R indicator. Titrate immediately with standard EDTA solution until the colour changes from pink to blue.

NOTE — If sharp end-point is not obtained, add 2 ml of potassium cyanide (10 percent, *m/v*) after the addition of triethanolamine.

A-17.4 Calculation

Calcium oxide (as CaO), percent by mass = $\frac{V \times F}{M} \times 100$
where

V = volume of standard EDTA solution required for titration, in ml;

F = CaO equivalent of the standard EDTA solution, in g/ ml; and

M = mass of the sample represented by the aliquot taken, in g.

ANNEX B

(Clause 5.3)

DETERMINATION OF MOISTURE

B-1 PROCEDURE

Spread uniformly on a dry, weighed petri dish about 1 to 2 g of the thoroughly mixed clay sample (see C-6.2) and weigh accurately. Dry it in an air oven at 105 to 110 °C for 3 h, cool in a desiccator and weigh. Repeat the process till constant weight is obtained. Record the loss in weight of the sample.

B-2 CALCULATION

Moisture, percent = $\frac{A}{B} \times 100$

where

A = loss of weight on drying, in g; and

B = weight of the sample taken, in g.

ANNEX C

(Clause 7.1)

SAMPLING OF CHINA CLAY FOR CERAMIC INDUSTRY

C-1 GENERAL REQUIREMENTS OF SAMPLING

In drawing, preparing, storing and handling test samples, the following precautions and directions shall be observed.

C-1.1 Samples shall not be taken in an exposed place.

C-1.2 Sampling instrument shall be clean and dry when used.

C-1.3 Precautions shall be taken to protect the sample, the material being sampled, the sampling instrument and the containers for samples from adventitious contamination.

C-1.4 The sample shall be placed in clean, dry air-tight glass or other suitable containers.

C-1.5 The sample containers shall be of such a size that they are almost completely filled by the sample.

C-1.6 Each sample container shall be sealed air-tight with a stopper after filling and marked with full details of sample, the date of sampling and other identification particulars.

C-1.7 The sample shall be stored in such a manner that during storage, the properties of the material do not get affected.

C-1.8 The sampling shall be done by a person or persons mutually agreed to between the purchaser and the supplier.

C-2 SCALE OF SAMPLING FOR MATERIAL PACKED IN CONTAINERS

C-2.1 Lot

In a single consignment, all the material belonging to the same grade and coming from the same supplier or source shall constitute a lot.

C-2.2 Sub-lot

For the purpose of sampling, all the material in a lot shall be divided into a suitable number of homogeneous sub-lots of approximately equal weight in accordance with col 1 and 2 of Table 4.

C-2.3 The number of containers to be sampled from each sub-lot is given in col 3 of Table 4. These containers shall be selected at random from the sub-lot. From each of these containers, a small but equal increment of material shall be taken.

C-2.4 All the increments from the sample containers in the same sub-lot shall be pooled together to constitute a gross sample so that there are as many gross samples as the sub-lots into which a lot has been divided.

C-3 SAMPLING FROM BULK

C-3.1 Lot

The part or whole of the material in the bulk belonging to the same grade and coming from the same supplier or source shall constitute a lot.

Table 4 Scale of Sampling for Containers
(Clauses C-2.2 and C-2.3)

No. of Containers in the Lot	No. of Sub-lots	No. of Containers to be Sampled from Each Sub-lot
(1)	(2)	(3)
Up to 10	1	All
11 to 200	2	5
201 to 500	3	10
501 to 2 000	4	15
2 001 and above	5	20

C-3.2 Sub-lot

For the purpose of sampling, the material in a lot shall be divided into a suitable number of homogeneous sub-lots of approximately equal weight in accordance with Table 5 by suitably marking the lines of demarcation on the surface of the bulk.

C-3.3 Sampling from bulk shall be carried out as far as possible when the material is in motion. For this purpose, the increments shall be drawn at regular

intervals, depending upon the rate of flow of the material of the sub-lot and the number of increments as given in col 3 of Table 5.

Table 5 Scale of Sampling for Bulk and Wagons
(Clauses C-3.2, C-3.3 and C-4.2)

No. of Containers in the Lot	No. of Sub-lots	No. of Containers to be Sampled from Each Sub lot
(1)	(2)	(3)
Up to 200	2	20
201 to 500	3	30
501 to 2 000	4	40
2 001 and above	5	50

C-3.4 All the increments from a sub-lot shall be pooled together to constitute a gross sample.

C-4 SAMPLING FROM WAGONS

C-4.1 Lot

In a single consignment, all the material belonging to the same grade and coming from the same supplier or source shall constitute a lot.

C-4.2 Sub-lot

For the purpose of sampling, all the wagons in a lot shall be divided into a suitable number of homogeneous sub-lots of approximately equal weight in accordance with Table 5.

C-4.3 A minimum of 25 percent of wagons shall be selected at random from the sub-lot. The corresponding number of increments to be taken from a sub-lot shall be distributed over the selected wagons with a view to determining the number of increments that should be taken from each of the selected wagons in the sub-lot.

C-4.4 All the increments taken from the selected wagons in a sub-lot shall be pooled together to constitute a gross sample.

C-5 PREPARATION OF SAMPLE

C-5.1 All the increments from the same sub-lot shall be thoroughly mixed to constitute a gross sample representing the sub-lot. The minimum size of the gross sample shall be about 3 kg. If the gross sample is less than this, additional number of increments shall be drawn so as to make up the required quantity.

C-5.2 The gross sample shall be suitably reduced by the method of coning and quartering or any other suitable method to about 750 g, which shall be divided into three portions called laboratory samples, one for the purchaser, and another for the supplier and the third as the referee sample, each duly placed in the sample container.

ANNEX D*(Foreword)***COMMITTEE COMPOSITION**

Ceramicware Sectional Committee, CHD 09

<i>Organization</i>	<i>Representative(s)</i>
CSIR-Central Glass and Ceramic Research Institute, Kolkata	DR SUMAN KUMARI MISHRA (Chairman)
Aditya Birla Insulator, Halol	SHRI MALLIKARJUN BANAGUNDI SHRI SUDHARSHAN C. (<i>Alternate</i>)
Ahmedabad Pottery Manufacturers Association, Naroda	SHRI RUPESH C. SHAH
All India Pottery Manufacturers' Association, Kolkata	SHRI GOUTAM HAZRA SHRI SANDIP KUMAR (<i>Alternate</i>)
Ants Ceramics Pvt Ltd, Thane	SHRI ASHWINI JAIN SHRI SABYASACHI ROY (<i>Alternate</i>)
Associated Soapstone Distributing Co Pvt Ltd, Jaipur	SHRI DILIP JHA SHRI RAJENDRA PAREEK (<i>Alternate</i>) SHRI AMIT SHARMA (<i>Young Professional</i>)
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Clay Craft Indian Pvt Ltd, Jaipur	SHRI BHARAT AGARWAL SHRI PRADIP KUMAR AGARWAL (<i>Alternate</i>)
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Government College of Engineering and Ceramic Technology, Kolkata	PROF RAM CHANDRA DAS PROF RITUPARNO SEN (<i>Alternate</i>)
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<i>Organization</i>	<i>Representative(s)</i>
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BUREAU OF INDIAN STANDARDS

Headquarters:

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Telephones: 2323 0131, 2323 3375, 2323 9402

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Regional Offices:

Telephones

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